Coordinate Systems and Datum Transformation in ArcGIS

Brittney White and Melita Kennedy
Where is my data?

Problem
Transformations

Projections

Horizontal

Vertical

Projections

Transformations
Horizontal coordinate systems
Geographic and Projected
What does a coordinate system tell us?

- Distance
- Location
- Direction
Q: How far is it from San Francisco to Los Angeles?

- 352.34 miles
- 690.67 kilometers
- 567.03 kilometers
- 620111.549 yards
Q: How far is it from San Francisco to Los Angeles?
A: It depends on the coordinate system.

- 352.34 miles
- 690.67 kilometers
- 567.03 kilometers
- 620111.549 yards
Q: What are the coordinates for Los Angeles?

(-118.25, 34.05)

(1276.333, 2421.545)

(2054060.514, 3897101.109)

(-13163527.521, 4035514.817)
Q: What are the coordinates for Los Angeles?
A: It depends on the coordinate system.

(-118.25, 34.05)
(1276.333, 2421.545)
(2054060.514, 3897101.109)
(-13163527.521, 4035514.817)
Direction

Q: In which direction is the North Pole?

- Down
- To the right
- Up
- Can’t, not on the map
Q: In which direction is the North Pole?
A: It depends on the coordinate system.

- Down
- To the right
- Up
- Can’t, not on the map
Two Kinds of Horizontal Coordinate Systems

- Geographic coordinate system
- Projected coordinate system
Geographic Coordinate System (GCS)

- 3D spherical surface

Point P has:
- Longitude – 80° E
- Latitude – 50° N
Geographic Coordinate System (GCS)
Projected Coordinate System (PCS)
Horizontal Coordinate System
Horizontal Coordinate System

Geographic Coordinate System
- Prime Meridian
- Datum
- Spheroid

Projected Coordinate System
- Projection
- Linear Unit
- Projection Parameters
Two Ways to Specify a Coordinate System

- Well-known ID
- Well-known text
Horizontal coordinate systems
Vertical coordinate systems
Height

Q: How high is Mount Everest?

- 8844.43 meters
- 29029 feet
- 8.850 kilometers
- 29017.16 feet
Height

Q: How high is Mount Everest?
A: It depends on the vertical coordinate system.

- 8844.43 meters
- 29029 feet
- 8.850 kilometers
- 29017.16 feet
Vertical Coordinate System (VCS)

- Defines the origin for height or depth
- Only vector data
The Origin for Height or Depth

Geometric model
The Origin for Height or Depth

Geometric model

Gravity related model

Geoid

Ellipsoid

Earth's surface
Gravity-Related Earth Model

- Geoid
  - Equipotential surface of the earth’s gravity
  - Complex shape
  - Modeled with geoid height / undulation (N)
Vertical Coordinate System
Datum vs. Vertical Datum

- **Datum**
  - Ellipsoidal datum
  - Ellipsoidal height ($h$)

- **Vertical datum**
  - Gravity-related datum
  - E.g. orthometric height ($H$)
Direction and Shift

• Direction
  - axis direction is positive for heights or depths

• Vertical Shift
  - parameter for a built-in offset from the VCS definition
Projections
Projecting to a Different Coordinate System
Why are there so many map projections?

- Shape
- Area
- Direction
- Distance
Web Mercator Projection

Q: Which is bigger?

- South America
- Greenland
- Antarctica
Web Mercator Projection

Q: Which is bigger?

South America ~ 17 840 000 km$^2$
Greenland ~ 2 166 000 km$^2$
Antarctica ~ 14 000 000 km$^2$
Web Mercator Projection vs. Reality
What is most important to preserve?

- Shape
- Area
- Direction
- Distance

Depends on what you are doing
Preserve Shape

- Stereographic
Preserve Area

- Albers equal-area conic
Preserve Direction and Distance

- Azimuthal equidistant
Transformations
Geographic and Vertical
Transforming Means Changing Datum

Earth-centered datum (WGS 84)
Transforming Means Changing Datum

Earth-centered datum (WGS 84)

Local datum (NAD 27)
Why do we need to transform our data?
Why do we need to transform our data?
Two Kinds of Transformations

Geographic (datum) transformation

Vertical transformation
Geographic (Datum) Transformation

NAD 1927 → NAD_1927_To_WGS_1984_1 → WGS 1984
Geographic (Datum) Transformation

NAD 1927 → WGS 1984

~NAD 1927 → WGS 1984

WGS 1984 → NAD 1927

~NAD 1927 → WGS 1984
Defined for Certain Area

- 33 transformations:

  - NAD 27
  - WGS 84
How do I find transformations?
Working with geographic transformations
Vertical Transformation

- New in ArcGIS 10.4 and Pro 1.4

Ellipsoidal Heights (NAD83)

Orthometric Heights (NAVD 88)

NAD_1983_To_NAVD88_CONUS_GEOID12B_Height
Vertical Transformation Methods

Geoid models
EGM2008
EGM84 and EGM96
GEOID12B
VERTCON

Vertical offset
Vertical offset and slope
ArcGIS (Pro) Coordinate Systems Data

- 1.5 GB additional data install

- GEOCON v1.0
- NTv2

- VERTCON
- GEOID12B
- EGM2008
  - 1’ x 1’ and 2.5’ x 2.5’

Geographic Transformations

Vertical Transformations
Vertical transformations
Now you understand…

Coordinate Systems

Projecting your data

Transforming your data
Unknown coordinate systems
Unknown coordinate systems

- ALWAYS define the coordinate system
- Good professional practice - help your successor
- Units are unknown
- Map scale is incorrect
- Geodatabase tools can’t use default values
What if I don’t know my data’s coordinate system?

• Check the data provider or source
• Check any existing metadata
• Similar data types
• What coordinate systems are used in the area?
  - http://www.epsg-registry.org
• Try using ArcMap to figure it out
  - http://esriurl.com/11518
  - HowTo: Identify an unknown coordinate system using ArcMap
• Lining Up Data in ArcGIS by Margaret Maher
Familiarize yourself with common coordinate systems

- Know what ones are used in the area
- Learn what the layer extents should be

<table>
<thead>
<tr>
<th>San Diego, California</th>
<th>NAD 1983</th>
<th>X / longitude</th>
<th>Y / latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographic</td>
<td>-116.67 °</td>
<td>33 °</td>
<td></td>
</tr>
<tr>
<td>UTM zone 11N</td>
<td>530,000 m</td>
<td>3,650,000 m</td>
<td></td>
</tr>
<tr>
<td>State Plane (California zone 6)</td>
<td>1,960,000 m</td>
<td>593,000 m</td>
<td></td>
</tr>
</tbody>
</table>
Where is my data?
Solution
Resources

• Don't forget the Knowledge Base / Technical Articles!
  - http://esriurl.com/11518

• Esri forums for user-to-user help
  - http://geonet.esri.com

• http://www.epsg.org
  - Database of coordinate systems & datums
  - Guidance Note 7-2

_Lining Up Data in ArcGIS_, Margaret Maher
Please Take Our Survey on the **Esri Events App**!

**Download the Esri Events app and find your event**

**Select the session you attended**

**Scroll down to find the survey**

**Complete Answers and Select “Submit”**